FOOD HABITS OF LEOPARD (*PANTHERA PARDUS FUSCA*), DHOLE (*CUON ALPINUS*) AND STRIPED HYENA (*HYAENA HYAENA*) IN A TROPICAL DRY THORN FOREST OF SOUTHERN INDIA[1]

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Food habits of the Leopard (*Panthera pardus fusca*) were studied in the Sigur (Nilgiri district) and Thalamalai (Erode district) Reserve Forests of Tamil Nadu, southern India from June to October 1997. A comparison of Leopard food habits with the diet of the co-predators, Dhole (*Cuon alpinus*) and Striped Hyena (*Hyaena hyaena*), in the study area was carried out to understand niche overlaps. Chital (*Axis axis*) was the major prey of the Leopard in both areas; found in 40% leopard scats in the highly disturbed area (HDA) and 65% in the less disturbed area (LDA). Other important prey species were Sambar (*Cervus unicolor*), Blackbuck (*Antilope cervicapra*), Black-naped Hare (*Lepus nigricollis*), Indian Wild Boar (*Sus scrofa*), Indian Porcupine (*Hystrix indica*), Common Langur (*Semnopithecus entellus*) and Indian Peafowl (*Pavo cristatus*). The Leopard had a wider niche-breadth value in the highly disturbed (0.32) than in the LDA (0.20). The food niche of the three predators – Leopard, Dhole and Striped Hyena overlapped considerably. Niche-overlaps were higher in the less disturbed than in the HDA. Prey preference estimates showed that the most favoured prey of the Leopard was Chital. Domestic livestock formed a sizeable portion of the Leopard diet in both areas; more in the highly disturbed (33.3%) compared to the less disturbed (14.7%). Twenty cases of livestock kills by Leopards were recorded during the 5-month study. Anthropogenic pressure is not the direct reason; depletion of prey base caused by disturbance and higher encounter rate with domestic livestock are possibly the reasons.

Key words: prey preference, *Panthera pardus fusca*, *Cuon alpinus*, *Hyaena hyaena*, conflict, thorn forest, southern India

INTRODUCTION

The Leopard *Panthera pardus fusca* is a large cat distributed throughout Peninsular India. According to Nowell and Jackson (1996) it is the most widely distributed of all the wild cats. It is found in almost every kind of habitat from rain forests of the tropics to deserts and temperate areas (Kitchener 1991). In Peninsular India, its principal habitat varies from tropical evergreen rain forest to open tropical dry thorn forest. It also lives outside forest areas (Prater 1971).

Leopards hunt by stalking, taking their prey opportunistically and mostly at night, especially where people have persecuted it (Nowell and Jackson 1996). The prey of Leopards varies in different geographical areas. In Kruger National Park, South Africa, Leopards were found to kill mainly medium-sized prey such as Impala (*Aepyceros melampus*), though a wide variety of small animals including hyraxes, civets and mongooses also formed part of their diet (Bailey 1993). In Tai National Park, Ivory Coast, leopards prey on about 30 species of animals (Hoppe-Dominik 1984). Small prey also constituted a significant proportion of Leopard diet in Tsavo, Kenya (Hamilton 1976). Bothman and Riche (1984) found that in the Kalahari Desert leopards fed on small prey like Bat-eared Fox (*Otocyon megalotis*), jackals (*Canis* spp.), genets (*Genetta* spp.), hares (*Lepus* spp.), duiker (*Cephalopus* spp.) and porcupine (*Hystrix* spp.). In the Serengeti, Tanzania, Bertram (1978) found 30 species in a sample of 150 Leopard kills. Muckenhirn and Eisenberg (1973) reported that in Sri Lanka leopards preyed mainly on Chital (*Axis axis*) and Indian Wild Boar (*Sus scrofa*), while also feeding on Sambar (*Cervus unicolor*), Common Langur (*Semnopithecus entellus*), Black-naped Hare (*Lepus nigricollis*), Indian Porcupine (*Hystrix indica*) and calves of domestic buffalo. In India, Schaller (1967), Johnsingh (1983), Karanth and Sunquist (1995, 2000) and Venkatraman *et al.* (1995) studied leopard food habits; the major prey reported were Chital, Sambar, Barking deer (*Muntiacus muntjak*), Goral (*Nemorhaedus* spp.) and livestock. According to Edgaonkar and Chellam (1998), the major prey of leopard was found to be domestic dog, domestic buffalos and rodents in Sanjay Gandhi National Park (SGNP), Maharashtra. In the Mundanthurai plateau of Tamil Nadu, Sathyakumar (1992) reported that leopards prey mainly on Sambar, Black-naped Hare, Chital and livestock. In Bandipur, Johnsingh (1983) found that 66% of Leopard kills were Chital. Chellam (1993) found that in Gir, 40% of Leopard scats were Chital and 25% Common Langur. In the tropical forest of Nagarhole, southern India, Karanth and Sunquist (1995) found that Chital constituted the major prey base of leopards.

Leopards have been found to coexist with other large carnivores across most of their range. In Asia, it shares its habitat with the Tiger and Dhole (Karanth and Sunquist 1995, 2000; Venkataraman *et al.* 1995). In Zaire, Central Africa, Hart *et al.* (1996) found the Leopard coexisting with the Golden Cat (*Felis aurata*) by specializing on different prey. In Nagarhole, southern India, Karanth and Sunquist (2000) found that the Tiger, Leopard and Dhole selectively killed different prey in terms of species, size and age-sex classes, allowing for the coexistence of all three predators.

In this paper we aim to study (i) the food habits of the Leopard in disturbed and undisturbed habitats, (ii) overlap of their diet with that of the Dhole (*Cuon alpinus*) and the Striped Hyena (*Hyaena hyaena*), (iii) assessment of habitat quality, wild prey abundance and human pressure near and away from the villages, and (iv) impact of leopards on domestic livestock. We use the results to suggest possible ways to minimise and mitigate human-leopard conflicts.

STUDY AREA

The study was carried out in the Sigur Reserve Forest (Nilgiris district) and part of Thalamalai Reserve forest (Erode district) (11° 30' 11° 35' N and 76° 45' 76° 52' E), Tamil Nadu state. The Sigur plateau abuts this area on the west. The study area acts as a corridor between the Western and Eastern Ghats. The perennial Moyar and Kukkalthorai Halla rivers drain the entire area, which receives rainfall mostly from the north-east monsoon between September and November. However, the annual rainfall is very low (400 mm) as the area falls in the rain shadow. The altitude is around 350 m above msl. Vegetation is tropical dry thorn forest (Champion and Seth 1968) dominated by *Strychnos potatorum*, *Canthium parviflorum*, *Zizyphus mauritiana*, *Azadirachta indica*, *Moringa concanensis*, *Hardwickia binata*, *Bridelia retusa* and *Diospyros montana*. The Moyar riverbeds in Mangalapatti Bhawanisagar and adjacent areas are dominated by an introduced species *Prosopis juliflora*.

The large mammal fauna in this area includes the Asian Elephant (*Elephas maximus*), Gaur (*Bos gaurus*), Sambar (*Cervus unicolor*), Chital (*Axis axis*), Blackbuck (*Antilope cervicapra*), Four-horned Antelope (*Tetracerus quadricornis*), Bonnet Macaque (*Macaca radiata*), Common Langur (*Semnopithecus entellus*), Indian Wild Boar (*Sus scrofa*) and Indian Porcupine (*Hystrix indica*). Mammalian predators include Leopard (*Panthera pardus*), Tiger (*Panthera tigris*), Asiatic Wild Dog (*Cuon alpinus*), Striped Hyena (*Hyaena hyaena*) and Jackal (*Canis aureus*). Other fauna of the study area include Black-naped Hare (*Lepus nigricollis*), Common Palm Civet (*Paradoxurus hermaphroditus*), Jungle Cat (*Felis chaus*), Indian Peafowl (*Pavo cristatus*), Grey Junglefowl (*Gallus sonneratii*), Python (*Python molurus*), Marsh Crocodile (*Crocodylus palustris*), Indian Star Tortoise (*Geochelone elegans*), Indian Black Turtle (*Melanochelys trijuga*), Leith's Softshell Turtle (*Aspideretes leithii*) and Monitor Lizard (*Varanus bengalensis*).

A large number of cattle are reared in the adjacent villages of Thengumarahada, Pudukadu, Hallimoyar and Kallampalayam. Cattle compete for food with natural prey of larger carnivores besides spreading diseases such as foot and mouth, rinderpest and anthrax to wild animals. Overgrazing by cattle is a serious problem in these villages. Firewood and timber collection by locals also contributes to the degradation of the forest.

METHODS

The study area was divided into 'Highly disturbed area' HDA (high prevalence of woodcutting and cattle grazing) and 'Less disturbed area' LDA (relatively little human disturbance). The HDA included 10 sq. km of dry thorn forest adjacent to the villages of Thengumarahada, Pudukadu and Hallimoyar. The less disturbed area covered an area of 10 sq. km, and was also dry thorn forest, but at least 10 km away from any village.

Leopards are known to be largely nocturnal and not easily seen (Bertram 1978). Direct observation of prey capture is not easy and hence most studies on leopard food habits rely on indirect evidence from kills and scats (Bertram 1978; Karanth and Sunquist 1995). In our study we use indirect evidence to understand the food habits of the Leopard, Dhole and Striped Hyena.

Scat analysis

Scats of leopards, dholes and striped hyenas were collected once a week each on Mangalapatti Road (12 km), Palamarapatti Road (12 km), Hallimoyar Road (8 km), and Bhawanisagar Road (8 km).

The scats were identified from their characteristic appearance and supplementary evidence in the form of tracks, scrapes and size of the scat (Karanth and Sunquist 1995). Scats were air-dried and kept in separate polythene bags.

For diet analysis, scats were soaked in water, washed, and strained thoroughly to separate prey remains like bones, hooves, hair, quills and feathers. Samples of hairs from the scats were washed in water, dried and passed through ether and xylene (Koppikar and Sabins 1975). They were then

mounted on a slide in liquid paraffin and examined under a binocular microscope (15x). At least twenty hairs were examined from each scat (Mukherjee *et al.* 1994). Prey species were identified using features such as colour, length, thickness and characteristic medullar configurations (Karanth 1993). Hair samples were also compared to reference slides prepared from hair of known species and collections of the Indian Institute of Science Research Station. Identification keys given by Koppikar and Sabins (1975), Oli (1993) and Easa (1995) were also used. Schaller's method (1967) was adopted to obtain the frequency and percentage of food items in scat (the annual prey requirement of the Leopard appears to be about 1,000 kg; based on this the frequency of food items in scats and their percentages were calculated). Jaws of ungulates were identified following Cohen's (1977) guidelines. Wilcoxon matched pairs test was done to look at the difference in highly disturbed and less disturbed areas within each species and also to compare dietary composition between pairs of species.

Kill data collection

An intensive search for kills over the entire study area was a daily routine. Clues like smell of carcass, alarm calls of Chital and Common Langur, predator signs and calls, and movement of vultures and crows aided in detecting kills. Whenever kills were found, the following information was recorded; identity of the predator by ancillary evidences such as tracks, scats, scrape marks, tooth marks, type of killing injury, feeding method and catching behaviour, the species killed, sex and approximate age of the individual; description of microhabitat.

Calculation of niche-breadth, niche-overlap and food preference indices

Niche breadth was estimated using formula described by (Hurlbert 1978): $Bi = 1/\sum Pi^2$

Bi = Levins' measure of niche breadth

where Pi is the proportion of individuals found in or using resource state 'i' or fraction of items in the diet. This measure was standardized to a scale of 0-1 by using the formula $B_A = (B-1)/(n-1)$

where B_A = Levins' standardised niche
B = Levins' resources of niche breadth
n = number of possible resource states

Niche-Overlap

The niche-overlap between leopards, dholes, and striped hyenas were calculated as described by Schoener (1970) using the following formula:

$$\text{Niche-overlap} = 1 - 1/2 \sum_{i=1}^{i=n} | P_{ij} - P_{ik} |$$

where 'P_{ij}' is the proportion of use of 'i' th resource by species 'j' and

'P_{ik}' is the proportion of use of 'i' th resource by species 'k'

Food Preference Index

Ivlev's (1961) index was used as an index of food preference:

Ivlev's index of selection = (U-A)/ (U+A)

where 'U' denotes percent use and 'A' denotes percent available and lies between +1 to -1.

Assessment of prey abundance

Prey abundance was estimated by two methods:

1. **Direct counts (encounter rates)**: Population of Chital, Blackbuck, and cattle were estimated based on direct counts. Known sites of prey aggregations were visited and animal numbers in each area were recorded. In addition to this, all wild prey and livestock encountered (encounter rate = number of animals sighted per km of trail walked) in the study area were recorded. The data so collected gave an approximate index of wild prey and livestock inhabiting the area. From these estimates, the prey biomass in the area was calculated by multiplying the number of animals of a species inhabiting the area with the average weight of the species. The direct count method is preferred to transect for the following reasons.

a. The prey species populations were very low (R. Arumugam pers. obs.) and the effort required would have been very high for species like Chital and Blackbuck.

b. Since the prey aggregate at known sites during the evening, direct counts should give a better estimate.

2. **Pellet counts**: Pellet count method was adopted to estimate the relative abundance of some of the more elusive, secretive and nocturnal animals (Indian Porcupine, Black-naped Hare and Sambar) which were not censused by the direct counts. This will give an indirect estimate of prey abundance. A grid was laid across the study area and random blocks were chosen for sampling. Fixed width transects (rectangular plots of 10 m x 2 m) were laid in these randomly chosen blocks and all the pellets (pellet groups) encountered in these strips counted. In all 66 plots were laid in the HDA and 59 plots in the LDA and the number of pellet groups of each species was recorded.

Assessment of Human disturbance

Tree density was estimated by counting all woody stems above 10 m x 2 m girth within the same plots that were used for estimating pellet abundance. Intensity of tree lopping

signs and cattle grazing signs were taken as a measure of the extent of human disturbance in an area. Lopping signs were also recorded in the same plots. Then the percentage of lopping was calculated as: $(n_l / N) \times 100$, where n_l = trees lopped, N = total trees

Similarly, cattle dung density per hectare (number of dung piles) was used to quantify the impact of livestock grazing in an area.

RESULTS

Extent of human disturbance in the two study sites

Strychnos potatorum, *Canthium parviflorum* and *Capparis zeylanica* were the major woody plant species in both the highly disturbed (HDA) and less disturbed (LDA) areas in the study sites. However, overall tree density was lower in the HDA (348.44/ha) than in the LDA (398.22/ha) (see appendix 1). Lopping signs were present on 9 plant species in the HDA and only on 2 species in the LDA (see appendix 1). *Strychnos potatorum* suffered the most in both areas, with all the trees of this species suffering damage in the HDA. The number of plants that suffered damage was 151.50/ha (43.48%) in the HDA and 76.16/ha (19.13%) in the LDA.

Scat Analysis

Leopard: Seventy-four leopard scats were analyzed, of which 45 were from the HDA and 29 from the LDA. Chital was the commonest prey in both as its remains constituted 35.3% of the scats in the highly disturbed, and 55.9% in the LDA (Table 1, Fig. 1). The Leopard's use of livestock was more in the highly disturbed (33.3%) than in the LDA (14.7%). Sambar was another common prey in both. Blackbuck remains were found only in the scats collected from the LDA. Wild boar and Indian Porcupine were a part of the diet only in the HDA.

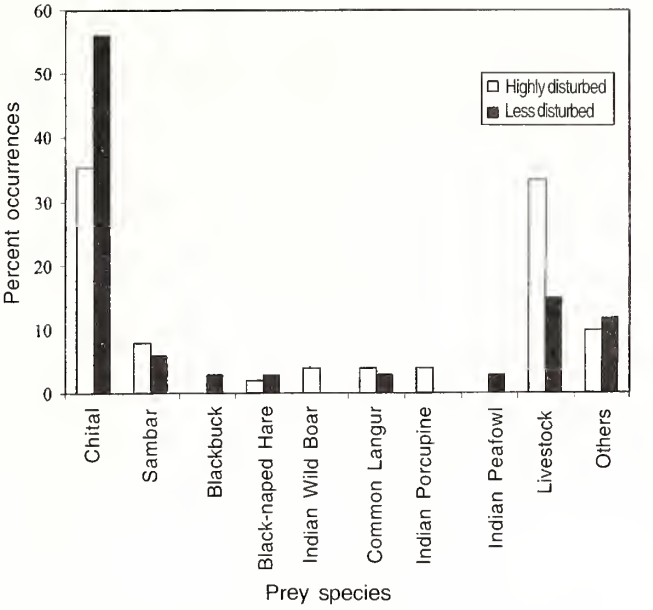

Fig. 1: Diet composition of Leopard in the highly disturbed and less disturbed areas

Table 1: Percent occurrence of different prey remains in Leopard, Dhole, and Striped Hyena scats in the highly disturbed and less disturbed areas during the study period

Species	% occurrence					
	Leopard (*Panthera pardus fusca*)		Dhole (*Cuon alpinus*)		Striped Hyena (*Hyaena hyaena*)	
	Highly Disturbed	Less Disturbed	Highly disturbed	Less Disturbed	Highly disturbed	Less disturbed
Chital	35.3	55.9	71.4	52.6	87.5	66.7
Sambar	7.8	5.9	4.8	0	0	0
Blackbuck	0	2.9	0	5.3	0	0
Black-naped Hare	1.9	2.9	14.3	26.3	0	11.1
Indian Wild Boar	3.9	0	0	5.3	0	0
Common Langur	3.9	2.9	0	0	0	0
Indian Porcupine	3.9	0	0	0	0	0
Indian Peafowl	0	2.9	0	0	0	0
Livestock	33.3	14.7	0	5.3	12.5	22.2
Others*	9.8	11.8	9.5	5.3	0	0

– Number of scats analysed in the highly disturbed and in the less disturbed area: Leopard 45 and 29, Dhole 21 and 16, and Hyena 8 and 9
– * Others' include reptilian scales and unidentified remains.

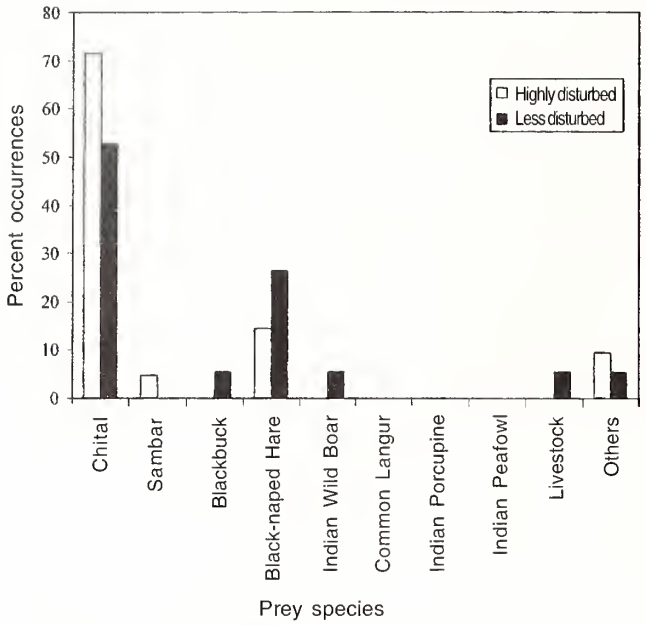

Fig. 2: Diet composition of Dhole in the highly disturbed and less disturbed areas

Leopards in both areas (Table 1) preyed on Black-naped Hare and Common Langur.

Percent occurrences of prey items in the Leopard's scat are given in Table 1. Wild prey constituted a major portion of Leopard diet in the less disturbed (88.4%) while livestock formed a significant portion (33.3%) in the HDA (Table 1).

The estimated biomass of different prey species taken by leopards are given in Table 2. In the HDA the biomass of livestock consumed (2,664 kg) exceeded all other prey species collectively (2,394 kg). On the other hand, leopards depended more on its natural wild prey in the LDA, with Chital forming the bulk (2,683.2 kg). Cattle biomass consumed by leopards in the LDA was 1,176 kg, under half that in the highly disturbed.

Dhole: Twenty-one scats from the highly disturbed and 16 scats from the LDA were analyzed. Chital was the major prey species in both areas and their remains were found in 71% of scats in the highly disturbed and 52.6% of scats in the LDA (Table 1, Fig. 2). Other prey items were Sambar and Black-naped Hare in the highly disturbed and Blackbuck, Black-naped Hare, and Indian Wild Boar in the LDA. One scat from the LDA had remains of livestock.

Striped Hyena: Seventeen scats, eight from the highly disturbed and nine from the LDA were analyzed. Only Chital (88%) and livestock (13%) remains were found in the scats from the HDA (Table 1, Fig. 3). In the LDA, Striped Hyena scats had remains of Chital (67%), Black-naped Hare (11%), and livestock (22%).

Prey abundance

Abundance and biomass availability of Chital and livestock were analysed. The LDA had a higher density and biomass of Chital than the HDA (12.1 animal/sq. km and 555 kg/sq. km vs 4.1 animal/sq. km and 185 kg/sq. km, respectively). On the other hand, livestock density and biomass were greater in the highly disturbed than the LDA (53.3 animal/sq. km and 1700 kg/ha vs 1.0 animal/sq. km and 200 kg/sq. km respectively). Relative abundance of other prey species in the highly disturbed and LDAs was assessed by the pellet densities (Table 3 & 4). Chital, Sambar and Blackbuck (the natural prey of leopard) were more abundant in the LDA while livestock relative density was greater in the HDA.

Table 2: Estimates of relative biomass of prey taken by leopards in the study area

Prey Species	Estimated (average) Live Weight [a]	Percent occurrence of prey remain in scats		Relative biomass [b] (kg)	
		Highly disturbed area	Less disturbed area	Highly disturbed area	Less disturbed area
Chital	48	35.3	55.9	1,694.4	2,683.2
Sambar	62	7.8	5.9	483.6	365.8
Blackbuck	48	0	2.9	0	139.2
Black-naped Hare	3	1.9	2.9	5.7	5.7
Indian Wild Boar	38	3.9	0	148.2	0
Common Langur	8	3.9	2.9	31.2	23.2
Indian Porcupine	8	3.9	0	31.2	0
Livestock	80	33.3	14.7	2,664	1,176

a- Approximate weights of prey species from Karanth and Sunquist (1995) except for livestock, for which an assumed weight of 80 kg was used; for blackbuck the average weight of 48 kg is assumed based on a similar species, the Chital.
b- Relative Biomass = Average weight x Relative frequency.

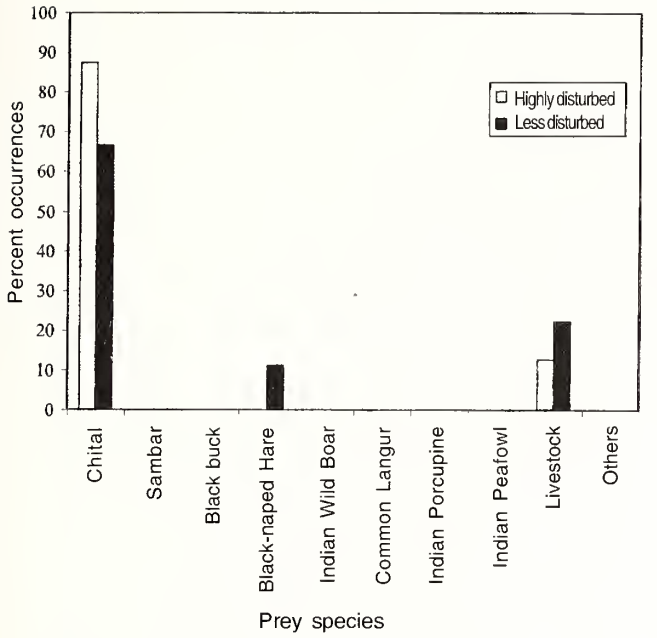

Fig. 3: Diet composition of Striped Hyena in the highly disturbed and less disturbed areas

There is no difference in the dietary composition in HDAs and LDAs of Leopard, Dhole and Striped Hyena using Wilcoxon Matched Pairs test with $p > 0.05$. There is also no difference in relative prey abundance between HDAs and LDAs using Wilcoxon Matched Pairs test ($p=1.0$). However, when the relative availability of prey and the relative proportion of prey eaten were compared using chi-square test, there was significant difference for all species (leopards $\chi^2 = 303.31$, $df = 6$, $p < 0.001$, dholes $\chi^2 = 311.32$, $df = 6$, $p < 0.001$ and striped hyenas $\chi^2 = 112.76$, $df = 6$, $p < 0.001$).

Table 3: Comparison of prey species abundance in the highly disturbed and less disturbed area of the study region during the study period (Based on pellet counts)

Prey Species	Relative Density (%)	
	Highly Disturbed area	Less Disturbed area
Chital	14.0	24.0
Sambar	7.5	12.1
Blackbuck	4.3	28.5
Black-naped Hare	27.6	21.5
Indian Wild Boar	2.5	2.4
Indian Porcupine	2.5	1.6
Livestock	41.6	9.9

Niche breadth

Leopards had a wider niche breadth in the HDA (0.323) than in the LDA (0.202), but dholes and striped hyenas had a wider niche breadth values in the LDA (Table 5).

Niche-overlap

Food niche-overlaps between the three predator species as derived from the data from scat analyses are given in Table 6. Leopards had a higher overlap with both dholes and striped hyenas in the LDA than in the HDA. The overlap between dholes and striped hyenas was higher in the HDA. In most cases, overlap values were higher than 0.5, indicating a high degree of similarity in food habits among the predators.

Prey preference

Prey preference values are shown in Table 7. Results showed that the Leopard had a positive preference for Chital in both areas with the values of +0.49 and +0.48 in highly disturbed and LDAs, respectively. A negative preference for Black-naped Hare was shown in both areas, while there was a positive preference for Sambar (+0.10) in the HDA and negative preference in the LDA (-0.25). Blackbuck remains were found in the scats of LDA only; the species had a negative

Table 4: Relative abundance of prey species and their proportions in the diet of predators

Prey species	Available prey (Expected)	Proportion of Leopard diet	Proportion of Dhole diet	Proportion of Striped Hyena diet
Chital	19	54.4	67.3	77.1
Sambar	9.8	8.1	2.6	0.0
Blackbuck	16.4	1.8	2.8	0.0
Black-naped Hare	24.5	2.9	21.8	5.6
Indian Wild Boar	2.5	2.3	2.8	0.0
Indian Porcupine	2.0	2.3	0.0	0.0
Livestock	25.8	28.2	2.8	17.4

Chi-square tests for abundance of prey species and their proportion in the diet of predator.
(Leopard – $\chi^2 = 303.31$, $df = 6$, $p < 0.001$,
Dhole – $\chi^2 = 311.32$, $df = 6$, $p < 0.001$,
Striped Hyena – $\chi^2 = 112.76$, $df = 6$, $p < 0.001$)

Table 5: Food niche - breadth values for Leopard, Dhole and Striped Hyena during the study period

Part of the study area	Predator Species		
	Leopard	Dhole	Striped Hyena
Highly disturbed area	0.323	0.094	0.031
Less disturbed area	0.202	0.202	0.107

Table 6: Food niche - overlaps among the three predator species during the study period

Part of the study area	Niche-Overlap values		
	Leopard and Dhole	Dhole and Striped Hyena	Leopard and Striped Hyena
Highly disturbed area	0.516	0.714	0.479
Less disturbed area	0.690	0.684	0.706

preference value of -0.78. Wild Boar and Indian Porcupine remains were recorded from Leopard scats in HDA only and their preference indices were +0.29. Livestock preference values were -0.04 in the HDA and -0.29 in the LDA. Chi-square tests showed that leopard prey preferences were significantly different in both habitats. ($\chi^2 = 159.34$, df = 9 and $p < 0.0$, for disturbed area; $\chi^2 = 255.06$, df = 9 and $p < 0.0$, for LDA)

Prey preference values for Dhole are given in Table 7. Chital had a positive prey-preference index in both areas. Even though Sambar and Black-naped Hare were fed on by dholes in the HDA, they had negative preference values of -0.17 and -0.35, respectively, in the HDAs. Blackbuck and cattle had negative preference values in the LDA, whereas Black-naped Hare and Indian Wild Boar had positive preference values.

For Striped Hyena, the prey preference index values were positive for Chital in both areas (Table 7). Livestock had a negative preference of -0.54 in the HDA and a positive preference of +0.38 in the LDA. Black-naped Hare remains were found only in the scats of the HDA with a negative preference (-0.32). Differences in prey preference were significant ($\chi^2 = 441.57$, df = 9 and P=<0.0, for HDA; $\chi^2 = 256.88$, df = 9 and P=<0.0, for LDA).

Kill data

In all, 30 leopard kills were recorded during the study period. Six human deaths and injuries to two had been recorded during 1992-1997 in the study area. Of the leopard kills, 20 were cattle, 9 were Chital and one was a Sambar. On four occasions, cattle escaped with injuries from leopards. In most cases, the prey was found eaten almost completely with only a few bones left. Most of the kills were found in the open dry thorn forest area. Of the 20 cattle killed, four each were adult males, subadult males and adult females; six were subadult females and two were calves. Among the nine Chital killed, three each were adult males, adult females and fawns. The two Sambar kills recorded were both sub adults. On a few occasions, the local people collected the skin and meat, especially when the kill was that of a Chital or Sambar. Once a crocodile was seen eating a cattle carcass killed by Leopard.

DISCUSSION

Prey selection by leopards

The major wild prey of Leopards in the study area was Chital, which constituted 35.3% and 55.9% of the diet in the highly disturbed and LDAs, respectively. This might be due to higher Chital population in the study area compared with other natural prey like Sambar. On the other hand, Sathyakumar (1988) found Sambar to be the preferred prey in the Mundanthurai plateau and attributed this to the fact that Leopard and Sambar are nocturnal animals and the Leopard, as a stalker, could easily stalk and kill Sambar. In both studies, as in Africa (Bailey 1993), ungulates constituted a major portion of the diet.

Schaller (1972) found the Leopard was mainly preying on animals in the 20-70 kg class. In our study also, smaller prey constituted a lower proportion of the Leopard's diet. However, Seidensticker *et al.* (1990), found that 36% of the Leopard's prey in Chitwan was under 25 kg. Leopards are highly adaptable animals that can co-exist with the tiger because their diet includes a variety of smaller animals that are usually ignored by tigers (Sankhala 1977).

Table 7: Prey preference indices for leopard, dhole and striped hyena in the highly disturbed and less disturbed area of the study region during the study period

Prey species	Leopard		Dhole		Striped Hyena	
	Highly Disturbed area	Less Disturbed area	Highly Disturbed area	Less Disturbed area	Highly Disturbed area	Less Disturbed area
Chital	+0.49	+0.48	+0.70	+0.40	+0.72	-0.54
Sambar	+0.10	-0.25	-0.17	0	0	+0.47
Blackbuck	0	-0.78	0	-0.67	0	0
Black-naped Hare	-0.85	-0.72	-0.35	+0.13	0	0
Wild Boar	+0.29	0	0	+0.40	0	-0.32
Indian Porcupine	+0.29	0	0	0	0	0
Livestock	-0.04	+0.29	0	-0.28	-0.54	+0.38

Black-naped Hare remains were found in the scats of Leopards both in the highly disturbed and LDA, in both of which Black-naped Hare pellets were quite abundant. Chellam (1993) did not find Black-naped Hare to be a preferred food item in the Mundanthurai plateau, while Karanth and Sunquist (1995) estimated that about 5% of prey in Nagarhole comprised Black-naped Hare, Sathyakumar (1988) stated that the presence of Black-naped Hare remains in the Leopards' diet might be because it could be easily hunted.

Arboreal prey (Indian Peafowl and Common Langur) comprised 3.9% in the HDA and 5.8% in the LDA. According to Sankhala (1977), the ability of the Leopard to climb trees with ease provides access to prey like arboreal animals like squirrels, langurs and other monkeys. Karanth and Sunquist (1995) also attributed the comparatively high degree of predation on Common Langur by Leopard at Nagarhole to the Leopard's greater arboreal habits and cryptic nature in comparison to the tiger. Another possible interpretation is that Leopards kill primates when they descend from trees (Singh 1985). Sathyakumar (1988) also observed Nilgiri Langur (*Presbytis johni*) and Bonnet Macaque (*Macaca radiata*) in the food of leopards in the Mundanthurai plateau, but Seidensticker (1983) stated that when the prey base was abundant the leopard would take the primates only occasionally. On the other hand, Schaller (1967) found leopards to be killing Common Langur frequently in Kanha Tiger Reserve, in Madhya Pradesh. Many other studies have documented the opportunistic nature of the Leopard's hunting pattern (Bothman and Le Riche 1984; Eisenberg 1986; Bailey 1993).

Remains of Indian Wild Boar were found only in 2 scats (4.4%) in the HDA. Similar findings were reported for the leopards of Mundanthurai plateau by Sathyakumar (1988). Killing Indian Wild Boars is not easy for leopards as they are formidable adversaries (Sankhala 1977; Karanth and Sunquist 1995).

Livestock were an important component in both the highly disturbed (33.3%) and less disturbed (14.7%) parts of the study area. Many livestock kills were recorded in the surrounding villages, and Sathyakumar (1988) also reported cattle kills in the Mundanthurai plateau. Seidensticker *et al.* (1990) found livestock to be a major component of the Leopard's diet at the fringes of the Royal Chitwan National Park, where the densities of domestic ungulates were higher than those of wild ungulates inside. Edgaonkar and Chellam (1998) were found domestic dogs, domestic buffalos and rodents are the major prey for leopard in SGNP. According to Singh (1986), an increased trend of cattle killing behaviour suggests highly disturbed behaviour.

Niche-overlaps with other predators

There was substantial dietary overlap between the Leopard, Dhole and Striped Hyena, with values from 0.516-0.690 between Leopard and Dhole, 0.479-0.706 between Leopard and Striped Hyena and 0.684-0.714 between Dhole and Striped Hyena. Colwell and Futuyma (1971) define niche overlap as joint use of a resource by two or more species. Hutchinson (1958) describes it as the area of space shared by two or more continuous niches. A substantial overlap between the diets of leopard and dhole in the Mundanthurai plateau was reported by Sathyakumar (1988) and by Karanth and Sunquist (1995) in Nagarhole. The results are consistent with the hypothesis of Bekoff *et al.* (1984) that larger predators take more prey types, since leopards took at least nine prey types, dholes 6 prey types and hyenas three prey types in the study area.

Dietary Preference

The present study showed that Chital was the preferred prey species for all the three predators studied, but overall prey preferences differed among them. A difference in the selectivity of prey species between leopards and dholes has been documented (Sathyakumar 1988; Karanth and Sunquist 1995). Livestock was selected by leopards according to availability, suggesting chance encounters were by primarily due to cattle grazing inside the natural habitats. Leopards did not seem to target cattle intentionally.

Though we identified hair from the scats to species level, we are not able to quantify the numbers of individuals, which could vary amongst predators. Therefore, these predators may not be competing with each other as much as the data from scats appears to show.

Human-leopard conflicts

Twenty cattle kills in five months, and eight human attacks in 1992-1997, of which six were fatal, were recorded in the study area. The problem clearly needs immediate attention. As Sawarkar (1989) pointed out, when large cats live in proximity to humans, some amount of conflict at the interface is inevitable. But the extent of cattle killing in the study area is very high and seemed to be the outcome of human interference in the natural habitat of Leopards, since more casualties were in the HDAs where large scale habitat destruction had taken place.

Man-eating by Leopards was another disturbing factor. Schaller (1967) mentioned that Leopards may eat humans occasionally. As Daniel (1996) mentions, when a Leopard becomes a man-eater it could be more dangerous than a Tiger because of its boldness and cunningness in entering villages. Corbett (1981) reports that leopards turn to human prey under

special circumstances. For instance when an epidemic killed a large number of people in the Himalaya, the bodies were not cremated but simply pushed down into the valleys and the leopards scavenging on the corpses acquired a taste for human flesh. According to Sunquist and Sunquist (1989), small island-like reserves of ideal habitat may be sources for man-eaters, with dispersing young adults being pushed out of prime habitat taking to man-eating in human habitation. Saberwal *et al.* (1994) also found it was sub-adult lions which were disproportionately involved in conflict situations in Gir and attributed this to the high density of lions in the park and poorer habitat quality at the fringes. The cattle-lifting and man-eating by leopards observed in the present study were mainly due to poor habitat quality and human intrusion into their natural habitats for wood cutting and cattle grazing. To overcome the problem the following management recommendations are suggested.

Because cattle compete for food with natural prey species such as Chital, Sambar, Blackbuck and Black-naped Hare, cattle populations should be reduced in villages near Leopard habitats. Since, man-eating and cattle-lifting traits in leopards may be transmitted from generation to generation, an individual Leopard that frequently kills cattle and human beings should be trapped and removed as soon as possible.

Leopards need a certain amount of vegetational cover to hunt wild prey, therefore wood collection in forest areas should be minimised. Local people use domestic dogs to kill wild herbivores such as Chital, Sambar and Black-naped Hare, which not only reduces wild prey density near villages but also drives the remaining wild prey to the interior of the forest. Hunting of wild animals should, therefore, be severely punished. Local people should be made to understand that poisoning is not a solution for the problem, since when a leopard is removed from its natural habitat another will soon occupy its territory.

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APPENDIX 1

Vegetation density and percentage of lopping signs in the highly disturbed and less disturbed regions of the study area

S. No.	Plant Species	Density (no./ha)		Lopping signs (% tree sampled)	
		Highly disturbed	Less disturbed	Highly disturbed	Less disturbed
1	*Strychnos potatorum* (Tree)	68.18	118.64	100.0	57.47
2	*Canthium parviflorum* (Shrub)	68.18	67.79	22.22	12.49
3	*Acacia arabica* (Tree)	30.30	25.42	50.0	0.00
4	*Acacia pennata* (Tree)	15.15	16.94	41.9	0.00
5	*Azadirachta indica* (Tree)	15.15	33.89	0.00	0.00
6	*Capparis zeylanica* (Shrub)	22.72	33.89	33.4	0.00
7	*Diospyros montana* (Tree)	15.15	8.47	0.00	0.00
8	*Ziziphus mauritiana* (Tree)	15.15	8.47	41.9	0.00
9	*Xeromphis spinosa* (Tree)	7.57	16.94	0.00	0.00
10	*Sapindus emarginata* (Tree)	7.57	33.89	0.00	0.00
11	*Bridelia retusa* (Tree)	15.15	0.00	0.00	0.00
12	*Ficus glomerata* (Tree)	15.15	0.00	100.0	0.00
13	*Grewia* spp. (Tree)	7.57	0.00	100.0	0.00
14	*Fluggea leucopyrus* (Shrub)	15.15	0.00	0.00	0.00
15	*Moringa concanesis* (Tree)	30.30	0.00	0.00	0.00
16	*Gardenia targida* (Tree)	0.00	16.94	0.00	0.00
17	*Chloroxylon swietenia* (Tree)	0.00	8.47	0.00	0.00
18	*Hardwickia binata* (Tree)	0.00	8.47	0.00	0.00

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